



Embedded Linux
Conference
North America

Open Source V2X Library

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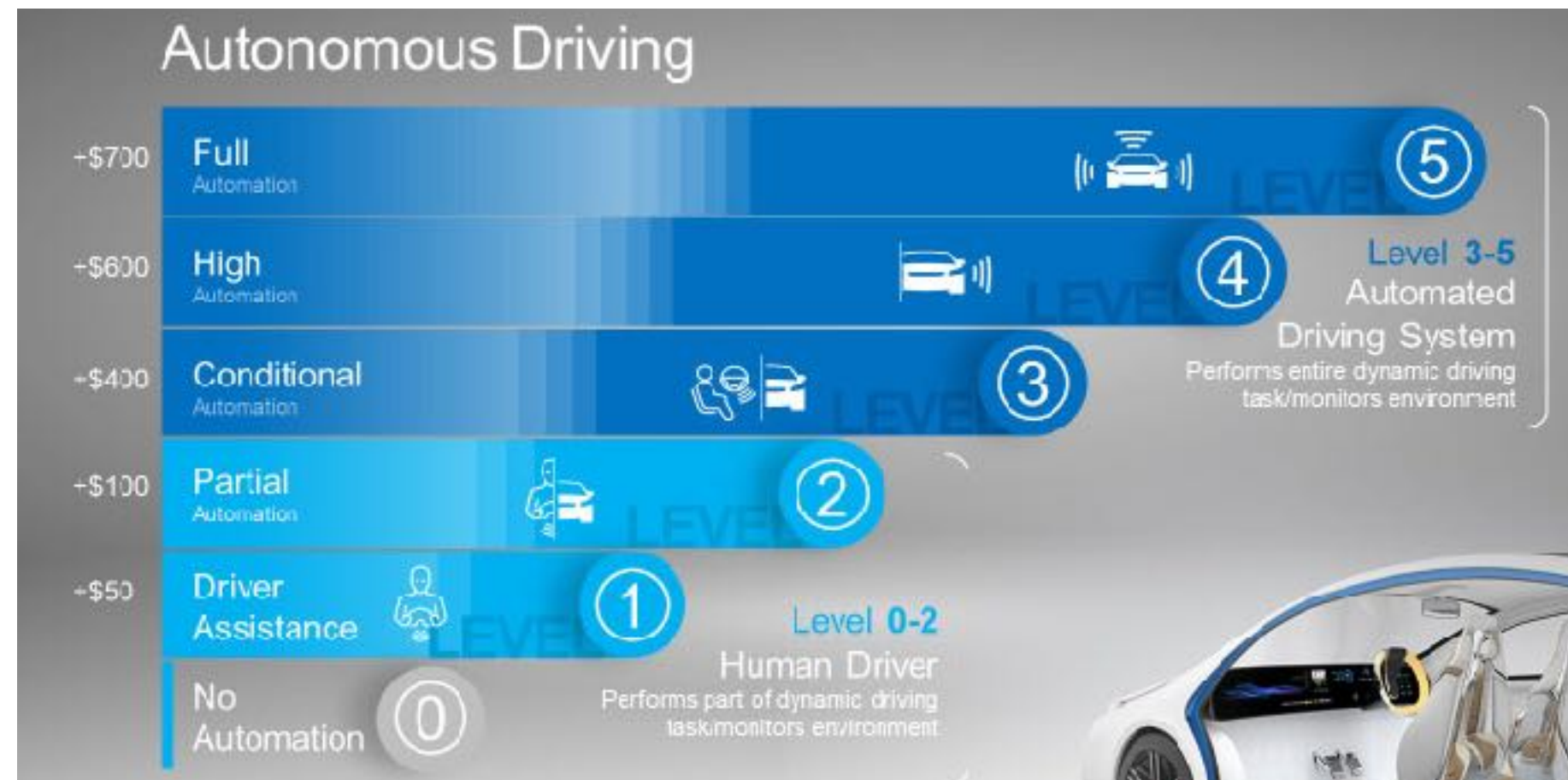


V2X (Vehicle-to-Everything) , What & Why Needs

Information Sharing Technology for Vehicles



Source : <https://networks.nokia.com/products/vehicle-to-everything>



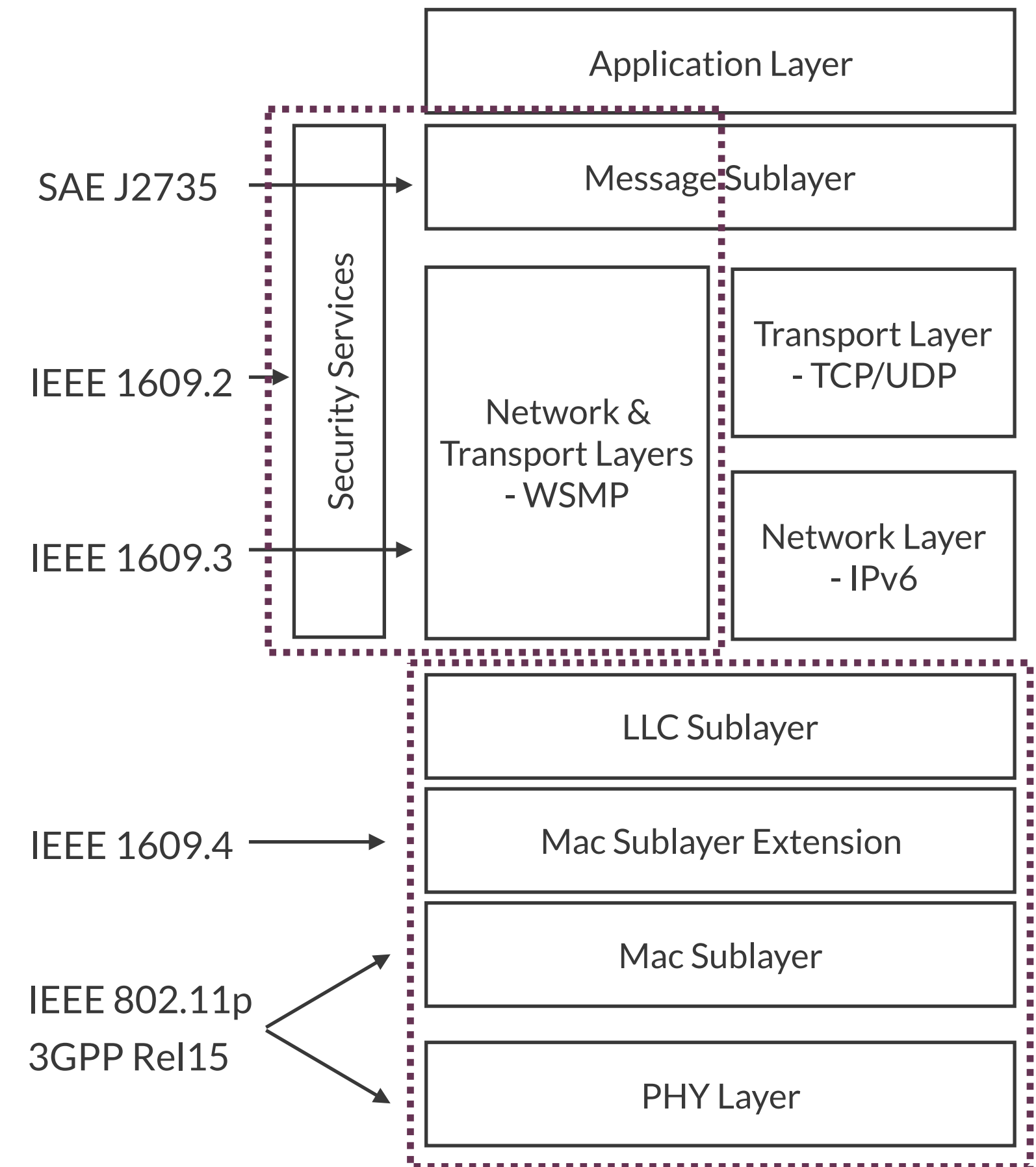
- Road Safety, Traffic Efficiency, Smart Mobility, Environmental Sustainability, Driver Convenience
- Low Latency and Non-Line-of-Sight Awareness Sensor for High Levels of Driving Automation
- Globally Deployed & On-Going Pilot (DSRC/C-V2X/5G)

V2X Communication Standards

Standard	Usage	OSI layer	Encoding
IEEE 802.11p 3GPP Rel15	WAVE PHY and MAC	1 and 2	
IEEE 1609.2	Security Services for Applications and Management Messages	N/A	ASN.1 COER
IEEE 1609.3	Networking Services	2, 3, and 4	
IEEE 1609.4	Multi-Channel Operation	2	
IEEE 1609.12	Identifier Allocations	N/A	
SAE J2735	Message Set Dictionary	7	ASN.1 UPER

< V2X Communication Standard for U.S. >

ASN.1 Handling



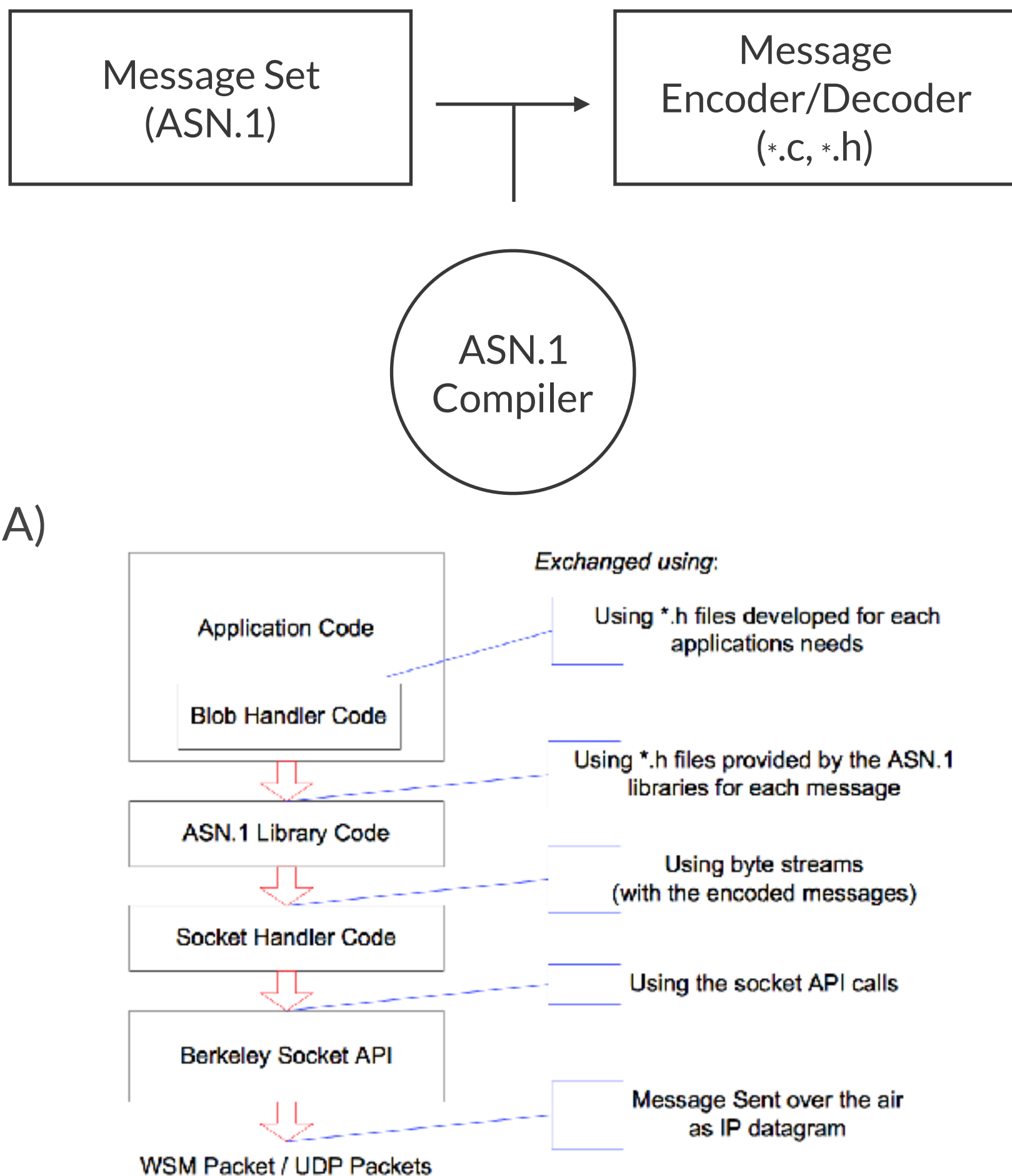
Proprietary device driver
Hardware not publicly available

ASN.1 & Message Set Dictionary

Basic Safety Message (BSM)
Common Safety Request (CSR)
Emergency Vehicle Alert (EVA)
Intersection Collision Avoidance (ICA)
Map Data (MAP)
NMEA_Corrections (NMEA)
Probe Data Management (PDM)
Probe Vehicle Data (PVD)
Road Side Alert (RSA)
RTCM_Corrections (RTCM)

...

< Messages of SAE J2735 >



< Protocol Stack Flow >

```
BasicSafetyMessage ::= SEQUENCE {
  -- Part I
  msgID          DSRCmsgID,          -- 1 byte

  -- Sent as a single octet blob
  blob1          BSMblob,

  --
  -- The blob consists of the following 38 packed bytes:
  --
  -- msgCnt      MsgCount,          -x- 1 byte
  -- id          TemporaryID,       -x- 4 bytes
  -- secMark     DSecond,           -x- 2 bytes

  -- pos        PositionLocal3D,
  -- lat         Latitude,          -x- 4 bytes
}
```

< ASN.1, from SAE J2735 >

```
Ieee1609Dot2Data ::= SEQUENCE {
  protocolVersion  Uint8(3),
  content          Ieee1609Dot2Content
}

Ieee1609Dot2Content ::= CHOICE {
  unsecuredData      Opaque,
  signedData         SignedData,
  encryptedData      EncryptedData,
  signedCertificateRequest Opaque,
  ...
}
```

< ASN.1, from IEEE 1609.2 >

ASN.1 Compiler & Handling

```
$ asn1c -fcompound-names -gen-PER -gen-OER ../asn1/1609dot2all.asn ../asn1/J2735_201603DA.asn
WARNING: Parameterized type REG-EXT-ID-AND-TYPE expected for REG-EXT-ID-AND-TYPE
at line 124 in ../asn1/J2735_201603DA.asn
WARNING: Parameterized type REG-EXT-ID-AND-TYPE expected for REG-EXT-ID-AND-TYPE
at line 125 in ../asn1/J2735_201603DA.asn
WARNING: Parameterized type REG-EXT-ID-AND-TYPE expected for REG-EXT-ID-AND-TYPE
at line 124 in ../asn1/J2735_201603DA.asn
WARNING: Parameterized type REG-EXT-ID-AND-TYPE expected for REG-EXT-ID-AND-TYPE
at line 125 in ../asn1/J2735_201603DA.asn
WARNING: Parameterized type PARTII-EXT-ID-AND-TYPE expected for PARTII-EXT-ID-AND-TYPE
at line 151 in ../asn1/J2735_201603DA.asn
Compiled HashedId10.c
Compiled HashedId10.h
Compiled HashedId8.c
Compiled HashedId8.h
Compiled HashedId3.c
Compiled HashedId3.h
Compiled SequenceOfHashedId3.c
Compiled SequenceOfHashedId3.h
Compiled Time32.c
Compiled Time32.h
Compiled Time64.c
Compiled Time64.h
Compiled ValidityPeriod.c
Compiled ValidityPeriod.h
Compiled IEEE1609dot2BaseTypes_Duration.c
Compiled IEEE1609dot2BaseTypes_Duration.h
Compiled GeographicRegion.c
Compiled GeographicRegion.h
Compiled CircularRegion.c
Compiled CircularRegion.h
Compiled RectangularRegion.c
Compiled RectangularRegion.h
```

< ASN.1 Compiling using <https://github.com/vlm/asn1c> >

```
Ieee1609Dot2Data_t *dot2 = NULL;
asn_dec_rval_t rval = oer_decode(NULL, &asn_DEF_Ieee1609Dot2Data,
    (void **)&dot2, &msg->data[0], msg->data.size());
if (rval.code != RC_OK) {
    RCLCPP_WARN(this->get_logger(), "failed to decode Ieee1609Dot2Data");
    ASN_STRUCT_FREE(asn_DEF_Ieee1609Dot2Data, dot2);
    return;
}

// asn_fprint(stdout, &asn_DEF_Ieee1609Dot2Data, dot2);

if (dot2->content->present == Ieee1609Dot2Content_PR_signedData)
{
    auto pub_msg = SecUnsecuredDataIndication();
    pub_msg.stamp = rclcpp::Clock().now();

    const SignedData_t *signedData = dot2->content->choice.signedData;
    const Ieee1609Dot2Data_t *ieee1609Dot2Data = signedData->tbsData->payload->data;
    const Opaque_t *opaque = &ieee1609Dot2Data->content->choice.unsecuredData;
```

< IEEE 1609.2 Decoding - ASN.1 COER >

```
MessageFrame_t *frame = NULL;
asn_dec_rval_t rval = uper_decode_complete(NULL, &asn_DEF_MessageFrame,
    (void **)&frame, &msg->data[0], msg->data.size());
if (rval.code != RC_OK)
{
    RCLCPP_WARN(this->get_logger(), "failed to decode MessageFrame");
    ASN_STRUCT_FREE(asn_DEF_MessageFrame, frame);
    return;
}

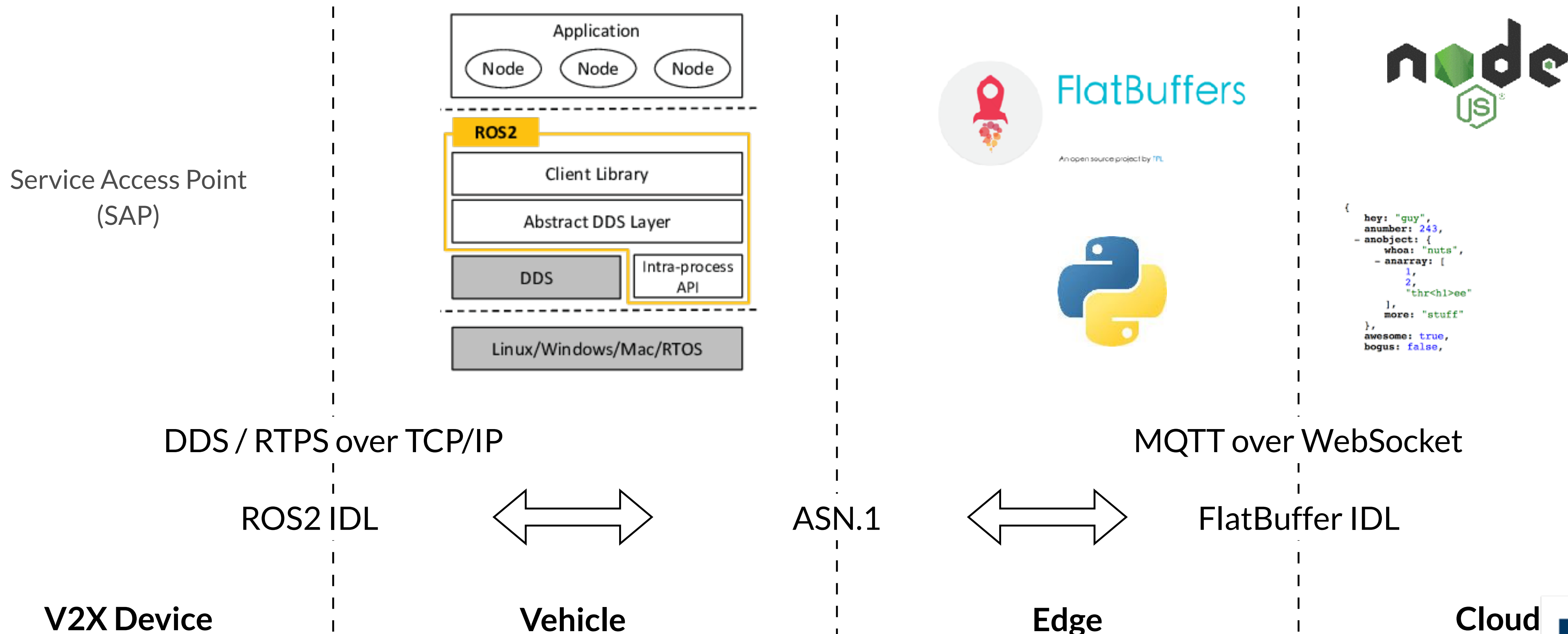
// asn_fprint(stdout, &asn_DEF_MessageFrame, frame);
```

< SAE J2735 Decoding - ASN.1 UPER >

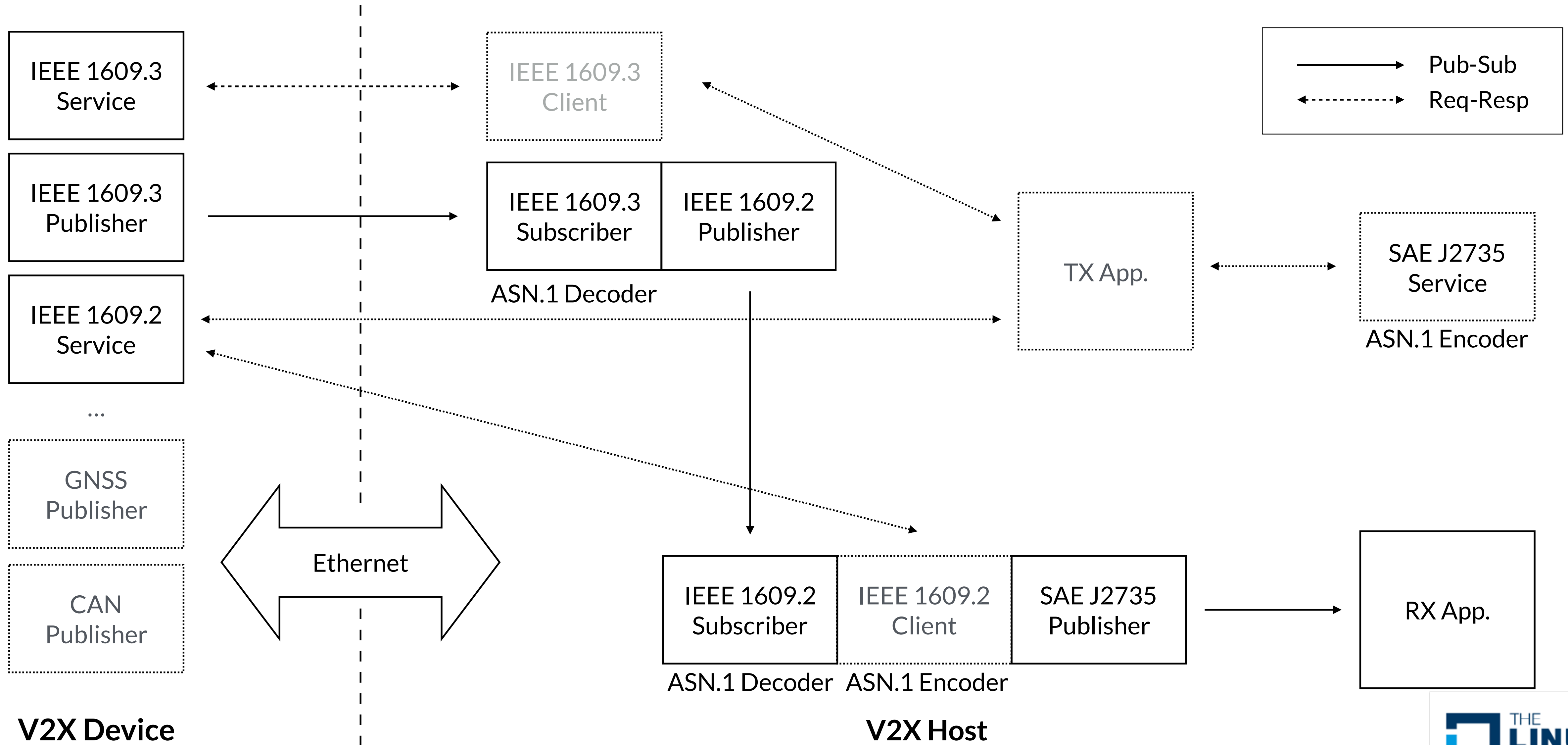
Design Concept

End-to-End Seamless Connectivity

Low Latency & High Reliability



ROS2 Node Connectivity



ROS2 IDL (Pub-Sub & Req-Resp)

SAP	Primitive	Specified in
WSM	WSM-WaveShortMessage.request	7.3.2
	WSM-WaveShortMessage.confirm	7.3.3
	WSM-WaveShortMessage.indication	7.3.4
WME	WME-ProviderService.request	7.4.2.2
	WME-ProviderService.confirm	7.4.2.3
	WME-UserService.request	7.4.2.4
	WME-UserService.confirm	7.4.2.5
	WME-WSMService.request	7.4.2.6
	WME-WSMService.confirm	7.4.2.7
	WME-ChannelService.request	7.4.2.8
	WME-ChannelService.confirm	7.4.2.9
	WME-TimingAdvertisementService.request	7.4.2.10
	WME-TimingAdvertisementService.confirm	7.4.2.11
	WME-Notification.indication	7.4.3.1
	WME-Get.request	7.4.4.1
	WME-Get.confirm	7.4.4.2
	WME-Set.request	7.4.4.3
	WME-Set.confirm	7.4.4.4
	WME-AddressChange.request	7.4.5.1
	WME-AddressChange.confirm	7.4.5.2
LSAP	DL-UNITDATA	7.5.2
	DL-UNITDATA	ISO/IEC 8802-2 (IEEE Std 802.2)
MLME	MLMEX-DELETETXPROFILE	IEEE Std 1609.4
	MLMEX-REGISTERTXPROFILE	IEEE Std 1609.4
	MLMEX-TA	IEEE Std 1609.4
	MLMEX-TAEND	IEEE Std 1609.4
	MLMEX-CHSTART	IEEE Std 1609.4
	MLMEX-CHEND	IEEE Std 1609.4
	MLME-GET	IEEE Std 802.11
	MLME-SET	IEEE Std 802.11
MAC	MA-UNITDATA	IEEE Std 802.11
	MA-UNITDATA	IEEE Std 1609.4
Sec	Sec-SignedData	IEEE Std 1609.2
	Sec-SignedDataVerification	IEEE Std 1609.2
	Sec-SecureDataPreprocessing	IEEE Std 1609.2

< Summary of primitives, from IEEE 1609.3-2016 >

```
# WSM-WaveShortMessage.indication
uint8      wsm_version
uint8      channel_number
uint8      data_rate # 0x2-0x7F, increments of 500 kb/s, IEEE802.11-2016
int8       transmit_power_used
uint8[<=8] channel_load # undefined yet
uint8      user_priority # 0-7
# uint16    length # 1 to WsmMaxLength - h, WsmMaxLength: def=1400, max=2302
uint8[<=2302] data # length is included
uint8[6]   peer_mac_address # EUI48
uint64     provider_service_identifier
```

< Publisher - Subscriber >

```
# WSM-WaveShortMessage.request
uint8      channel_identifier
uint8      time_slot
uint8      data_rate # 0x2-0x7F, increments of 500 kb/s, IEEE802.11-2016
int8       transmit_power_level
uint8[<=8] channel_load
uint8      info_elements_indicator
uint8      user_priority # 0-7
uint64     expiry_time # 0~(2^64-1)
uint16     length
uint8[<=2302] data
uint8[6]   peer_mac_address # EUI48
uint64     provider_service_identifier
---
builtin_interfaces/Time stamp
# WSM-WaveShortMessage.confirm
int32      result_code
```

< Request - Response >

BasicSafetyMessage RX Demo

For Device Emulation
IEEE 1609.3 Publisher

```
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400429.673883019
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400429.773100781
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400429.873437510
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400429.974059083
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.073017126
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.173972382
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.273907827
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.373668946
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.474294708
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.574058305
[INFO] [ieee1609dot3_pub]: ieee1609dot3: 1566400430.674247839
```

IEEE 1609.3 Subscriber
IEEE 1609.2 Publisher

```
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400429.573275498, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400429.674481414, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400429.773635297, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400429.874190935, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400429.974684503, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400430.073674913, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400430.174751892, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400430.274535065, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400430.374250054, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400430.474895738, 248
[INFO] [ieee1609dot3]: ieee1609dot2: 1566400430.574952132, 248
```

IEEE 1609.2 Subscriber
SAE J2735 Publisher

```
[INFO] [ieee1609dot2]: saej2735: 1566400429.573698724
[INFO] [ieee1609dot2]: saej2735: 1566400429.674947088
[INFO] [ieee1609dot2]: saej2735: 1566400429.774137383
[INFO] [ieee1609dot2]: saej2735: 1566400429.874619226
[INFO] [ieee1609dot2]: saej2735: 1566400429.975169057
[INFO] [ieee1609dot2]: saej2735: 1566400430.074094117
[INFO] [ieee1609dot2]: saej2735: 1566400430.175107600
[INFO] [ieee1609dot2]: saej2735: 1566400430.275001258
[INFO] [ieee1609dot2]: saej2735: 1566400430.374640149
[INFO] [ieee1609dot2]: saej2735: 1566400430.475399407
[INFO] [ieee1609dot2]: saej2735: 1566400430.575431142
```

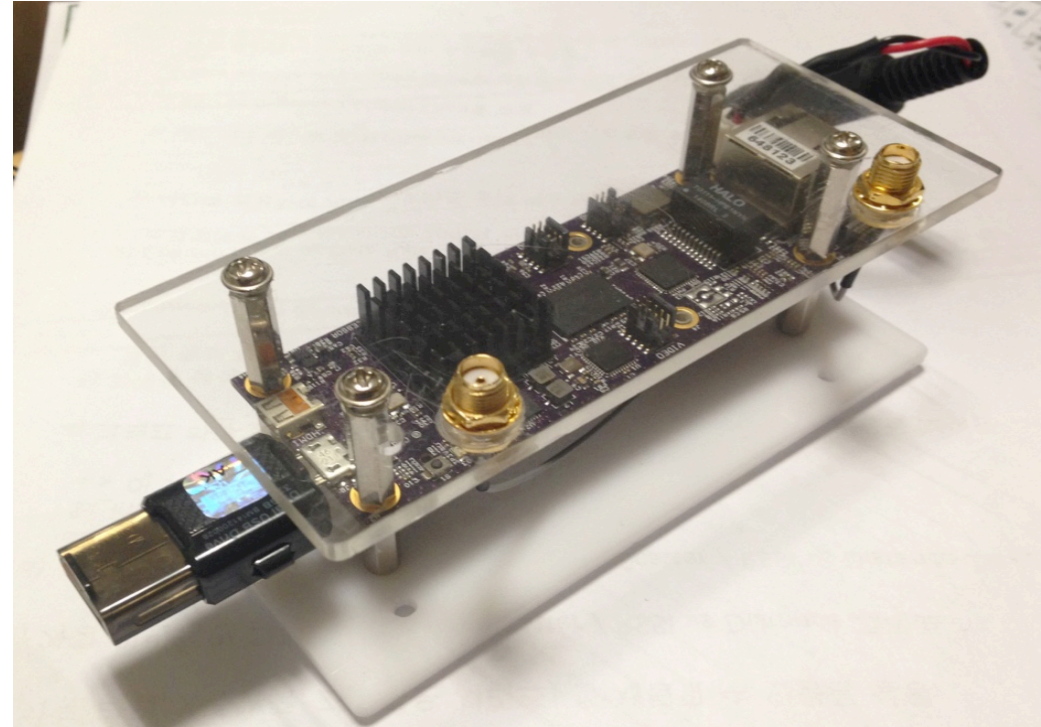
SAE J2735 Subscriber

```
[INFO] [saej2735]: 1566400429.573698724
[INFO] [saej2735]: 1566400429.674947088
[INFO] [saej2735]: 1566400429.774137383
[INFO] [saej2735]: 1566400429.874619226
[INFO] [saej2735]: 1566400429.975169057
[INFO] [saej2735]: 1566400430.074094117
[INFO] [saej2735]: 1566400430.175107600
[INFO] [saej2735]: 1566400430.275001258
[INFO] [saej2735]: 1566400430.374640149
[INFO] [saej2735]: 1566400430.475399407
[INFO] [saej2735]: 1566400430.575431142
```

```
speed: 0
heading: 0
angle: 0
accel_set:
  lon: 0
  lat: 0
  vert: 0
yaw: 0
brakes:
  wheel_brakes: 128
  traction: 0
  abs: 0
  scs: 0
  brake_bcost: 0
  aux_brakes: 0
size:
  width: 0
  length: 0
---
stamp:
  sec: 1566400430
  nanosec: 575431142
message_id: 20
basic_safety_message:
- core_data:
  msg_cnt: 46
  id:
  - 0
  - 0
  - 0
  - 0
  sec_mark: 228
  lat: 0
  lon: 0
  elev: 0
  accuracy:
    semi_major: 0
    semi_minor: 0
    orientation: 0
  transmission: 7
  speed: 0
  heading: 0
  angle: 0
  accel_set:
    lon: 0
    lat: 0
    vert: 0
    yaw: 0
  brakes:
    wheel_brakes: 128
    traction: 0
    abs: 0
    scs: 0
    brake_bcost: 0
    aux_brakes: 0
  size:
    width: 0
    length: 0
---
```

SAE J2735
Topic Echo

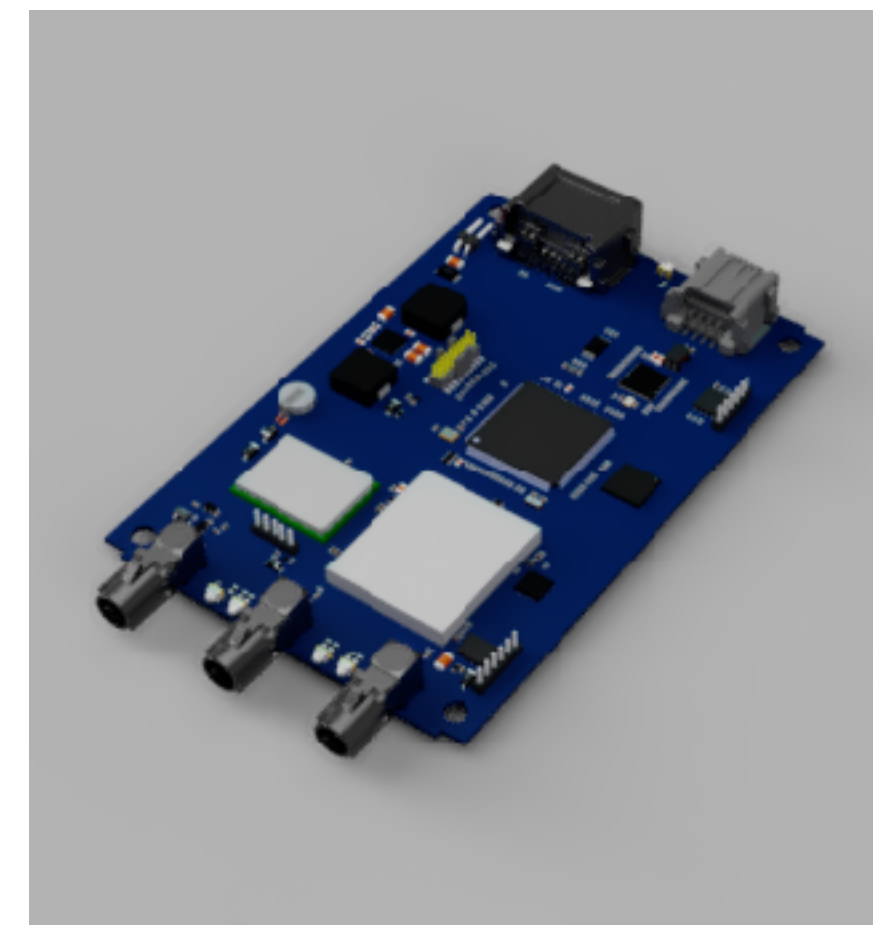
Low Cost V2X Device ?



How to Begin V2X Development on Linux, Automotive Linux Summit 2015

Single Board Computers w/ mini PCI-E socket

Freescale™ i.MX6 800MHz Dual Lite with AR9592 mini PCI-E Card



< Low Cost V2X Device, On-Going Project >

Thank you

<https://github.com/libv2x>